Eur J Vasc Endovasc Surg **17**, 480–485 (1999)
Article No. ejvs.1999.0825

Angiographic Runoff Score as a Predictor of Outcome Following Femorocrural Bypass Surgery

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Objective: *to evaluate the efficacy of the revised* ad hoc *scoring system in predicting the outcome of femorocrural bypass surgery.*
Design: *retrospective study.*
Materials and methods: *seventy-seven infrainguinal bypass procedures to the crural arteries were performed in 69 patients with critical leg ischaemia. Preoperative angiographic findings were graded according to the revised* ad hoc *scoring system and other preoperative angiographic measures.*
Results: *the revised* ad hoc *scores were valuable in predicting the outcome of these grafts. The status of the outflow artery throughout its length had a great impact on the long-term outcome in terms of secondary patency, leg salvage, patients alive with legs, and survival rates.* In situ *autogenous saphenous grafts achieved the best immediate and long-term results.*
Conclusions: *the revised* ad hoc *angiographic scoring method is useful in predicting the outcome of patients undergoing femorocrural arterial reconstruction. Patients with an outflow artery completely open throughout its length had excellent long-term results.*

Key Words: Tibial artery; Peroneal artery; Runoff; Critical limb ischaemia; preoperative angiography; Outcome prediction.

Introduction

An accurate prediction of the likelihood of success of surgical reconstruction for critical limb ischaemia (CLI) would improve limb salvage rates and reduce cost.[1,2]

Patients with high peripheral resistance due to extensive atherosclerotic disease are at high risk for graft failure, and Peterkin *et al*. have shown an association between preoperative angiographic findings and the runoff resistance.[3,4] Subsequently, Rutherford *et al*.[5] described a revised version of the *ad hoc* scoring system. We decided to evaluate the applicability of this new method in a series of 77 femorocrural bypasses.

Materials and Methods

Clinical data and preoperative angiographic findings of 69 patients with CLI who underwent 77 bypass procedures to the crural arteries were reviewed.

According to the European Working Group on CLI,[6] an ankle systolic pressure of ≤ 50 mmHg or a toe systolic pressure of ≤ 30 mmHg were assumed as objective diagnostic criteria for CLI. Medial sclerosis prevented accurate preoperative measurements of the ankle–brachial index in six cases (9%) and we were not able to measure the preoperative systolic toe pressure in 13 cases (17%). These patients had low ankle pulse-volume recording amplitudes, all below 5 mm. The diagnosis of chronic CLI was defined also by the clinical symptoms and signs: 32 patients (42%) had rest pain only, whereas foot ulcer or gangrene was encountered in 45 legs (58%).

All patients underwent preoperatively selective angiography to evaluate the extent of arterial disease and to choose the appropriate inflow and outflow vessels. The preoperative angiographic findings of the runoff vessels were graded according to the revised version of the *ad hoc* scoring system proposed by Rutherford *et al*.[5] (Tables 1 and 2). This scoring method is available for all cases except for the distal anastomosis to the tibioperoneal trunk. Therefore, we decided to assign the role of runoff artery to the posterior tibial or peroneal artery whenever one of these vessels was occluded. If both the arteries were

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1078–5884/99/060480+06 $12.00/0

Table 1. Calculation of angiogram score of patients undergoing bypass grafting to the crural arteries as proposed in the revised version of recommended standards for reports dealing with lower extremity ischaemia.[5]

Site of distal anastomosis	Arterial segment	Resistance value	Weight	Subscores	Total
Anterior tibial artery	Distal anterior tibial artery	. . x	2=		
	Pedal arch	. . x	1=	+___ sum	+1=total angiogram score
Posterior tibial artery	Distal posterior tibial artery	. . x	2=		
	Pedal arch	. . x	1=	+___ sum	+1=total angiogram score
Peroneal artery	Pedal runoff	. . x	2=		
	Collaterals to anterior and posterior tibial arteries	. . x	1=	+___ sum	+1=total angiogram score

Table 2. Resistance values of runoff arteries.[5]

	Degree of occlusion				
	3	2.5	2	1	0
Major runoff vessels	Occluded throughout length	Occluded less than $\frac{1}{2}$ of length; visible collaterals	50% to 99% greatest stenosis	20% to 49% greatest stenosis	Less than 20% greatest stenosis
Pedal runoff	No primary pedal artery patent	Partially patent or fully patent beyond critical in-line occlusive lesion	In-line continuity with patent outflow vessel but incomplete arch	One or more subcritical stenoses distally but no in-line	Fully patent pedal runoff (<20% stenosis)
Pedal arch	Little or no arch visualised	—	Diseased or partially occluded arch	Patent arch with no retrograde outflow	Completely patent arch connecting with retrograde flowback into the other pedal artery

at least partially open, the sum of the resistance values of both posterior and peroneal arteries was added to the resistance value of the pedal arch. Furthermore, in all cases we have graded the entire length of the crural arteries including proximal to the future bypass anastomosis according to the resistance values assigned by the revised *ad hoc* scoring system to a major outflow artery (Table 2). The sum of these values was added to a base resistance value of one so as to define the global angiographic status of the crural arteries, herein referred to as the crural score. In the same way, the status of the pedal arch was graded.

The outcome of patients having a completely patent outflow artery or with stenosis of less than 20% even proximally to the anastomotic site (resistance value = 0) was compared with the outcome of patients having a more diseased outflow artery throughout its length (resistance value ≥ 1). Patients' data and preoperative risk factors are listed in Table 3.

Outcome measures have been defined according to the recommended standards proposed by Rutherford *et al*.[5] Thirty-day postoperative outcome was defined as immediate outcome. The graft patency was assessed every 3 months during the first year and every 6 months thereafter. Graft patency was determined by clinical pulse examination, ABI measurements and by standard duplex scan when indicated. Angiography was performed whenever symptoms recurred or there was a suspicion of threatened graft failure. Postoperative immediate haemodynamic success was defined as an improvement of the ABI of more than 0.15 until 30 days after surgery. The mean follow-up period was 13.4 months (range, 0–42.2 months).

Data were statistically analysed with the use of a microcomputer database (SPSS for Windows 7.5, SPSS Inc., 444 North Michigan Avenue, Chicago, IL 60611, U.S.A.). The Cox regression model and Kaplan–Meier estimate were used to estimate graft patency, leg salvage, survival and success, defined as "patients alive with legs". The Cox regression model and the likelihood-ratio test with the help of a backward selection were used to estimate the impact of variables on the clinical outcome. We tried to avoid the risk of including too many predictive variables in the model as four different angiographic scoring systems were tested. This was done despite their mutual dependence in multivariate analysis with a knowledge that the strongest will mask the others. Each scoring system was also tested alone (SAS-program, SAS Institute Inc., Cary, North Carolina, U.S.A.). The Chi-squared and Fisher's

Table 3. Clinical data.

No. of patients/bypasses	69/77
Sex (M/F)	47/22
Mean age (range)	71.8 (46–89)
Rest pain	32 (42%)
Foot ulcer	35 (45%)
Foot gangrene	10 (13%)
NIDD/IDD	10 (13%)/21 (27%)
Hypertension[a]	38 (49%)
Heart disease[b]	41 (53%)
Cerebrovascular disease	12 (16%)
Previous vascular surgery	28 (36%)
Median preoperative ankle–brachial index (range)	0.32 (0.1–0.88)
Inflow artery	
External iliac artery	1 (1%)
Common femoral artery	51 (66%)
Superficial femoral artery	14 (18%)
Deep femoral artery	7 (9%)
Above-knee popliteal artery	2 (2%)
Below-knee popliteal artery	1 (1%)
Prosthesis	1 (1%)
Outflow artery	
Anterior tibial artery	30 (39%)
Posterior tibial artery	28 (36%)
Peroneal artery	12 (16%)
Tibioperoneal trunk	7 (9%)
Median revised *ad hoc* runoff score (range)	3.5 (1–9.5)
Median crural score (range)	7.5 (1–9.5)
Median pedal arch score (range)	3 (1–4)
Completely patent outflow artery	33 (43%)
Reconstruction material	
Autogenous saphenous vein *in situ*	55 (71%)
Autogenous saphenous vein *ex situ*	4 (5%)
Autogenous arterial graft	1 (1%)
Combined PTFE/autogenous vein graft	1 (1%)
PTFE	6 (8%)
Various combinations of autogenous vein grafts	9 (12%)
PTFE plus Miller's cuff	1 (1%)

NIDD: non-insulin-dependent diabetics; IDD: insulin-dependent diabetics; [a]: it is defined according to the criteria of the Finnvasc registry as diastolic blood pressure >95 mmHg and systolic blood pressure >160 mmHg, or the patient is under medical treatment for hypertension; [b]: it is defined according to the criteria of the Finnvasc registry as angina, signs of myocardial ischaemia on ECG, myocardial infarction, or previous coronary artery bypass grafting.

exact tests were used to analyse categorical data, and the Mann–Whitney test was used to analyse continuous data. Receiver-operating characteristic (ROC) curves were used to test the adequacy of the runoff scoring system and to define an appropriate cutoff value. An area under the ROC curve for a test greater than 0.5 plus twice the standard error was considered statistically significant.

Results

Four patients (5%) died during the 30-day postoperative period. Two patients (3%) were in the intensive care unit for more than 5 days. Twenty-one grafts (27%) occluded during the 30-day postoperative period. Among them, there were 12 *in situ* autogenous saphenous grafts (57%), three spliced autogenous vein grafts (14%), one *ex situ* autogenous saphenous vein graft (5%), four prosthetic grafts (19%), and one prosthetic graft plus Miller's cuff (5%). Postoperative complications are listed in Table 4.

Table 4. Postoperative complications.

Graft occlusion	21 (27%)
Wound edge necrosis	8 (10%)
Haematoma	5 (6%)
Deep-wound infection	3 (4%)
Seroma	1 (1%)
Cardiac	8 (10%)
Respiratory	5 (6%)
Sepsis	1 (1%)
Cerebrovascular	1 (1%)

Immediate haemodynamic success was achieved in 51 cases (81%) among 63 patients with available preoperative and postoperative ABI values.

At 1-month, 1-year, 2-year, and 3-year follow-up, the primary patency rates were 69%, 52%, 42%, and

Table 5. Impact of different risk factors on the outcome of femorocrural bypasses according to multivariate analysis (MA) and univariate analysis (UA) (*p*-values).

	Revised *ad hoc* scoring system	Reconstruction material[a]	Status of the leg[b]	Diabetes mellitus	Crural score	Status of the outflow artery[c]	Pedal arch
Immediate haemodynamic success	**0.03 (MA)** **0.001 (UA)**	**0.02 (MA)** **0.01 (UA)**	**0.003 (MA)** **0.003 (UA)**	0.28 (MA) NS 0.35 (UA) NS	0.58 (MA) NS **0.004 (UA)**	0.51 (MA) NS **0.003 (UA)**	0.82 (MA) NS 0.83 (UA) NS
Immediate primary patency	0.59 (MA) NS 0.39 (UA) NS	0.78 (MA) NS 0.12 (UA) NS	0.45 (MA) NS 0.36 (UA) NS	0.93 (MA) NS 0.81 (UA) NS	0.85 (MA) NS 0.92 (UA) NS	0.72 (MA) NS 0.60 (UA) NS	0.26 (MA) NS 0.25 (UA) NS
Immediate secondary patency	0.51 (MA) NS **0.05 (UA)**	**0.01 (MA)** 0.12 (UA) NS	**<0.0001 (MA)** **0.0003 (UA)**	0.52 (MA) NS 0.30 (UA) NS	0.92 (MA) NS 0.12 (UA) NS	0.64 (MA) NS 0.25 (UA) NS	**0.05 (MA)** 0.18 (UA) NS
Primary patency	0.53 (MA) NS **0.02 (UA)**	0.09 (MA) NS **0.03 (UA)**	**0.03 (MA)** 0.22 (UA) NS	0.99 (MA) NS 0.94 (UA) NS	0.50 (MA) NS 0.25 (UA) NS	0.17 (MA) NS 0.10 (UA) NS	**0.04 (MA)** **0.04 (UA)**
Secondary patency	0.75 (MA) NS **0.02 (UA)**	**0.0002 (MA)** **<0.00001 (UA)**	0.18 (MA) NS 0.26 (UA) NS	0.65 (MA) NS 0.60 (UA) NS	0.26 (MA) NS 0.07 (UA) NS	**0.03 (MA)** **0.02 (UA)**	0.71 (MA) NS 0.16 (UA) NS
Leg salvage	0.85 (MA) NS **0.002 (UA)**	**0.007 (MA)** **0.0009 (UA)**	**0.05 (MA)** 0.10 (UA) NS	**0.05 (MA)** 0.07 (UA) NS	0.71 (MA) NS **0.05 (UA)**	**0.04 (MA)** **0.02 (UA)**	**0.01 (MA)** **0.02 (UA)**
Alive with legs	0.79 (MA) NS **0.04 (UA)**	**0.004 (MA)** **0.002 (UA)**	0.15 (MA) NS 0.69 (UA) NS	**0.003 (MA)** **0.001 (UA)**	0.69 (MA) NS **0.0009 (UA)**	**0.02 (MA)** **0.002 (UA)**	0.44 (MA) NS 0.09 (UA) NS
Survival	0.86 (MA) NS 0.39 (UA) NS	— 0.85 (UA) NS	0.95 (MA) NS 0.31 (UA) NS	**0.01 (MA)** **0.02 (UA)**	**0.003 (MA)** **0.001 (UA)**	0.57 (MA) NS **0.008 (UA)**	0.19 (MA) NS 0.19 (UA) NS

NS: not statistically significant; [a]: *in situ* autogenous saphenous vein/other types of grafts; [b]: Fontaine III/Fontaine IV; [c]: completely open outflow artery throughout its length (or stenosis of less than 20%: resistance = 0)/diseased outflow artery throughout its length (resistance value ≥ 1).[5] Figures in bold are significant ($p<0.05$).

42%, the secondary patency rates were 83%, 73%, 66%, and 66%, the leg salvage rates were 94%, 80%, 76%, and 76%, survival rates were 92%, 83%, 82%, and 76%, while 88%, 69%, 64%, and 64% of patients were alive with legs.

The results of multivariate and univariate analysis for the evaluation of the impact of the revised *ad hoc* scores, the crural score, the presence of a completely open outflow crural artery, the status of the pedal arch, the reconstruction material, the Fontaine status, and diabetes mellitus on the outcome of these patients are listed in Table 5.

In patients with completely open or mildly diseased outflow track graft patency, leg salvage and survival were far better than if outflow track was compromised (Figs 1–4). The use of *in situ* vein decreased failure and amputation rates. Diabetes increased morbidity and mortality.

ROC curve for the revised *ad hoc* score in predicting the immediate secondary patency (area under the curve: 0.66; S.E.: 0.26) was not statistically significant, but the best cutoff point of the method was 7.5.

Discussion

Failures of infrainguinal bypass grafts during the 30-day postoperative period are attributed mainly to technical or judgement errors, underlying hypercoagulable state and inadequate outflow vessels, whereas late failures have been associated with intrinsic graft or anastomotic problems as well as progression of the atherosclerotic disease.[7–10] In particular, hypercoagulable abnormalities have been shown to be one of the major causes of immediate postoperative graft failure, a subject that has not been widely investigated and is potentially responsible for poor results not related to technical factors.[9] The fact that such disorders tend to affect the early outcome more than the long-term outcome of arterial reconstructions may explain why none of the preoperative risk factors taken into account in this study had any statistical significance in predicting immediate primary patency of femorocrural bypass grafts.

Since an association between the angiographic findings and the runoff resistance has been shown,[4] the value of preoperative angiography in being potentially useful in staging the extension of atherosclerotic disease of the lower extremity arteries has been variously evaluated. Controversy exists on the reliability of preoperative angiographic findings,[11,12] but evidence of a certain value in predicting the outcome of infrainguinal arterial reconstructions exists.[7,13–18] However, most of these studies included small numbers of infrainguinal bypass grafts to outflow arteries of different levels,[5] usually using different scoring methods. In the present

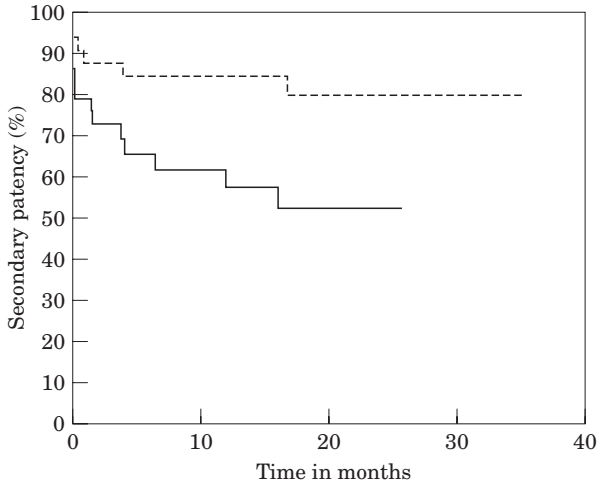

Fig. 1. Secondary patency after femorocrural bypass in the subgroup of patients without (——) and with (– – –) a completely open outflow artery or stenoses of less than 20% throughout its length.

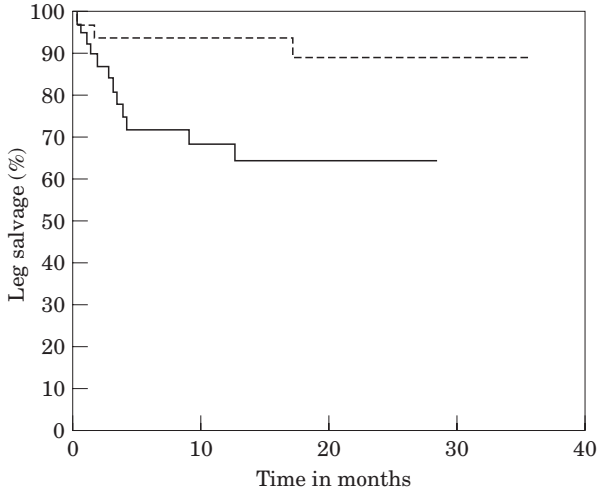

Fig. 2. Leg salvage after femorocrural bypass in the subgroup of patients without (——) and with (– – –) a completely open outflow artery or stenoses of less than 20% throughout its length ($p=0.02$).

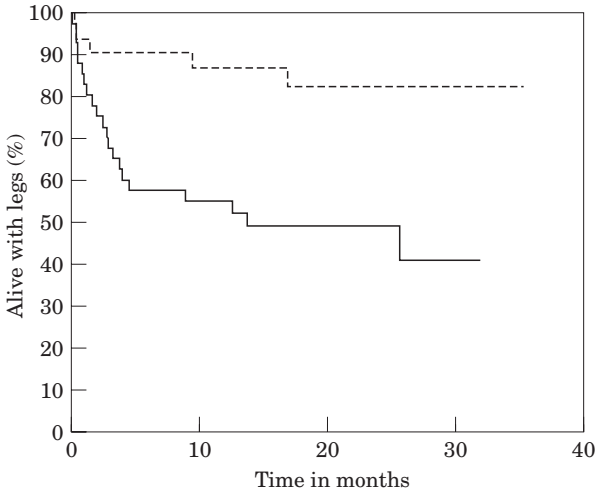

Fig. 3. Patients alive with legs after femorocrural bypass in the subgroup of patients without (——) and with (– – –) a completely open outflow artery or stenoses of less than 20% throughout its length ($p=0.002$).

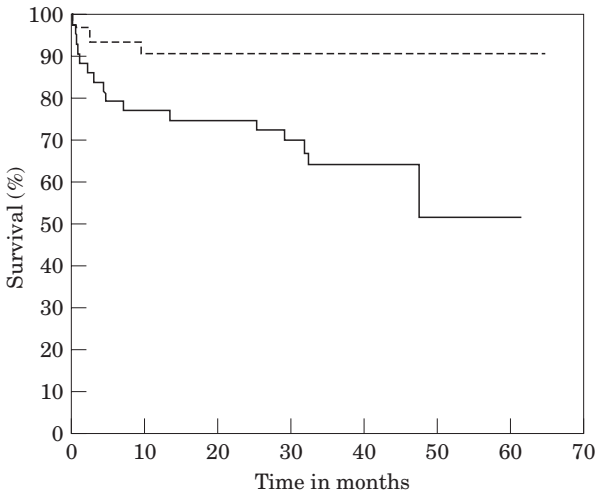

Fig. 4. Cumulative survival after femorocrural bypass in the subgroup of patients without (——) and with (– – –) a completely open outflow artery or stenoses of less than 20% throughout its length ($p=0.008$).

study, the revised version of the *ad hoc* classification has been retrospectively evaluated in a series of femorocrural bypasses. This classification showed statistically significant ability to predict the long-term outcome of such grafts, but in multivariate analysis this ability was masked by inclusion of the angiographic status of the outflow artery as well as that of pedal arch into the analysis. In particular, the presence of an outflow crural artery completely open throughout its length, or with mild degree stenoses, was found to be of great value in predicting the long-term outcome (Figs 1–4). This observation suggested an eventual pitfall of the *ad hoc* score in taking into account only the status of the outflow artery distal to the anastomosis. An outflow artery completely open throughout its length may, therefore, contribute in a different way to the runoff than an artery which is completely occluded or severely diseased proximally to the distal anastomosis.

Interestingly, the global status of the crural vessels, as defined by the crural score, and the presence of a completely open outflow crural artery had impact on the survival and the rate of patients who survived with legs. This means that the angiographic findings may correlate with the degree of atherosclerotic disease affecting coronary and cerebral circulation. This observation is of great clinical importance, as these parameters can be useful in identifying those potentially

long-term survivors who may maintain independent life by a leg salvage operation.

This study confirms that angiographic findings predict the long-term outcome of patients undergoing an infrainguinal bypass grafting to the crural vessels. The revised *ad hoc* scoring system showed a fairly good value in predicting the outcome of these grafts, but other angiographic parameters, i.e. the presence of a completely open or mildly diseased, outflow artery had a great impact on the patency, leg salvage, and survival outcomes.

Acknowledgements

We are most grateful to Anita Mäkela, R.N., for collection of data, and to Jukka Ollgren. M.Sc., for his expert assistance in the statistical analysis.

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Accepted 23 November 1998